Design of Modified Reduced Dimensional Subspace Channel Feedback Codebook for Massive Mimo System

S.Srinivas, P. Ramchandar Rao, J. Tarun Kumar, M. Sampath Reddy

Abstract*: The use of Lens antenna array with millimeter wave massive MIMO (multiple-input-multiple-output) system remarkably reduces the number radio frequency chains, high data rates are possible if the dimension of the equivalent channel is reduced after the beam selection. In frequency division duplex system codebooks are used to feedback equivalent channel to base station; however, no dedicated codebooks are available for LAA millimeter wave systems. In order to overcome the drawback, a proposed method is implemented such as modified reduced-dimensional sub-space codebook (M-RDSC) for millimeter wave massive MIMO systems. In the Proposed work, angle coherence time is used to build high dimensional vectors in the channel subspace, thereby these vectors are used to develop modified reduced dimensional sub-space codebook for feedback channel in millimeter wave massive MIMO system by taking the advantage of lens and beam selector. Finally, the equivalent channel aims to show performance through the use of the proposed M-RDSC and feedback to Base Station. The proposed system shows that the feedback overhead is made proportional to a few dominant paths per user. The overall performance of the proposed method is computed with the help of MATLAB R2018b version.

Index Terms*: Millimeter wave massive MIMO, Codebook, frequency division duplex, Lens antenna array.

I. INTRODUCTION

Millimeter wave massive Multiple input multiple output system is one of the trending technology in advanced era of wireless communication, but still it suffers from high isotropic path loss , large antenna gain, large number of RF chains and high cost of implementation to mitigate this loses now a days the design of MIMO systems using Lens antenna array. The millimeter wave signals coming from different directions are concentrated to different positions on a lens antenna so that the conventional spatial channel is converted into the beam-space channel thereby decreases MIMO dimension and RF chains. A high data rate can be desired by executing downlink transmit pre-coding (TPC) as an advantage of beam selection at the base station[3], which is depending on the reduced dimensional equivalent channel. In a frequency division duplex system, the equivalent channel uses dedicated codebook in a feedback path to give a signal to the base station. In Random Vector Quantization (RVQ) the equivalent channel vector does not follow the Rayleigh distribution, so codebook designed based on RVQ is not applicable to millimeter wave massive MIMO systems using on LAA[9]. In the proposed work high dimensional vectors are produced in the channel subspace by using the concept of angle coherence time, thereby these vectors along with beam selector and antenna lens are used to produce modified reduced dimensional sub-space codebook. The proposed system shows that the feedback overhead is made proportional to a few dominant paths per user.

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II. BACKGROUND WORK

The use of Lens antenna array with beam selection reduces the number radio frequency chains required, Fig 1 illustrates how a Spatial channel is converted into a Beam space channel[4], the use of lens with ULA antenna greatly simplifies design, with this the signals are coming from different directions are focused to a different positions on antenna. The use of lens with ULA antenna is termed as Lens antenna array.

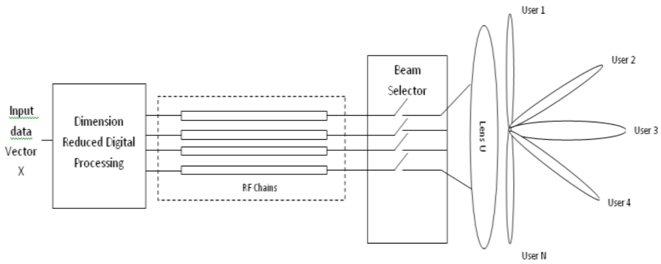

Fig.1 Millimeter wave massive MIMO system with lens antenna array

Let us consider N number of transmitting antennas at the base station and 'm' number of user antennas (N > m), In ray channel model the channel vector can be expressed as

$$h_m = \sum_{j}^{p_m} G_{m,j}\ u(\psi_m, j) \quad (1)$$

Where p_m tells about number of dominant paths, $G_{m,j}$ gives the complex gain of the jth path.

In equation (1) steering vector $u(\psi_m, j)$ is expressed as

$$u(\psi_m, j) = \frac{1}{\sqrt{N}}[1, e^{-i2\pi\psi_{m,j}}, -\ -\ -, e^{-i2\pi\psi_{m,j}(N-1)}]^T$$

(2) Where

$$\psi_{m,j} = \frac{l}{\lambda}\sin(\theta_{m,j})$$

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$\theta m, j$ gives an angle of departure, l indicates base station antenna spacing.
With the help of steering vector the channel vector can be rewritten as

$$h_m = U_m G_m \quad (3)$$

Where

$$U_m = \left[u(\psi_{m,1}), u(\psi_{m,2}), ----, u(\psi_{m,p_m}) \right]$$

$$G_m = [G_{m,1}, G_{m,2}, ----, G_{m,p_m}]$$

The lens used in lens antenna array can be characterized by using Discrete fourier transform, which is expressed as

$$w = [u(0), u(\delta), ---, u(\delta(N-1))]^H \quad (4)$$

Where $\delta = \frac{1}{N}$

So the received signal is expressed as

$$y_m = \sqrt{\frac{P}{m}} h_m^H w^H A q_x + n_m$$

$$y_m = \sqrt{\frac{P}{m}} (h_m^b)^H A q_x + n_m \quad (5)$$

Where P gives transmitted power, A indicates Beam selector

And $A \in C^{N \times M_{RF}}$

M_{RF} will gives numbers of RF chains used.

The data vector $X = [x_1, x_2, ----, x_m]^T$

The beam space channel vector is expressed as

$$h_m^b = w \ h_m \quad (6)$$

Reduced equivalent channel is expressed as

$$h_m^e = A^H \ h_m^b \quad (7)$$

III. PROPOSED METHOD

The first step in proposed method is to produce large dimensional vectors using channel subspace, there by these vectors are used to produce reduced dimensional subspace codebooks. To calculate channel subspace the channel vectors are distributed in the column of U_m during angle of coherence time[2] , the channel subspace can be expressed as

$$e_{m,j} = U_m Z_{m,j} \quad (8)$$

Where $Z_{m,j} \in e^{p_m \times 1}$

Using $e_{m,j}$ the Modified reduced dimensional subspace codebook can be written as

$$R_d = \left\{ r_{m,1}, r_{m,2}, ----, r_{m,2^B} \right\} \quad (9)$$

Where B gives number of bits used in feedback path

Where $r_{m,j} \in c^{M_{RF} \times 1}$

and $r_{m,j} = A^H w e_{m,j} \quad (10)$

IV. SIMULATION RESULTS

The following parameters are considered for simulation N=128, m=8, p=3 and different values of M_{RF}. The simulation results shows that the proposed system with practical scenario and perfect equivalent channel with ideal scenario are producing more or less same results even though the SNR is increasing, the proposed system produces much better performance than RVQ based codebook.

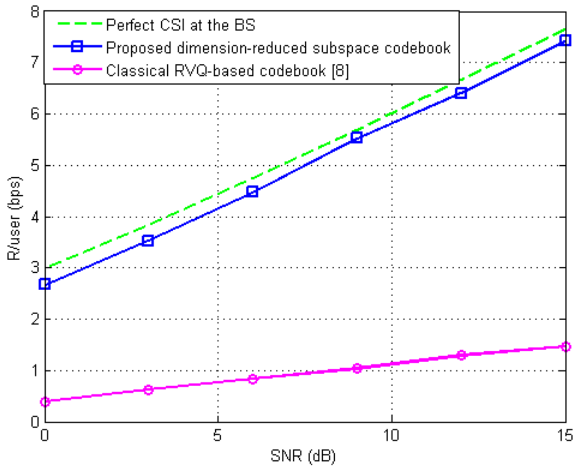

Fig.2. User rate comparison for perfect equivalent channel at Base station and practical feedback channel with N=128, m=8, p=3 and M_{RF}=24.

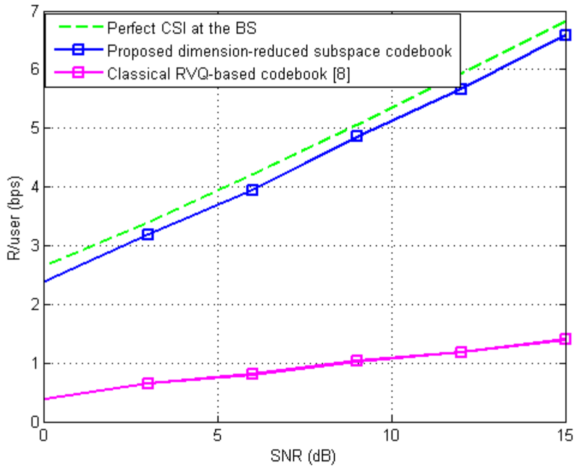

Fig.3. User rate comparison for perfect equivalent channel at Base station and practical feedback channel with N=128, m = 8, p =3 and M_{RF} = 12.

V. CONCLUSION

In the Proposed work, Angle coherent time is used to create large dimensional vectors in the channel sub-space, these vectors are used find modified reduced dimensional subspace codebook in view of lens and beam selector. Finally, the performance of proposed method is much superior to equivalent channel in the ideal case and also the proposed system shows that the feedback overhead is made proportional to a few dominant paths per user.

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